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(54) IMPROVEMENTS IN OR RELATING TO BEARING ASSEMBLIES EMPLOYING SENSING MEANS FOR SENSING MOTION OR POSITION

(71) We, RANSOME HOFFMANN POLLARD LIMITED, a British Company of New Street, Chelmsford, Essex, CM1 1PU, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

The present invention relates to bearing assemblies, incorporating sensing means for sensing positional relationships or motion.

Mechanical assemblies employing electromagnetic tachogenerators are known per se. However, these known assemblies are bulky and complex and there is a need for simpler constructions in which standard units, such as rotary bearings, can be utilized without extensive modification.

UK patent specifications 1 504 791 and 1 504 792 describe various forms of bearing assemblies of a particularly compact nature where sensing means providing a signal signifying the relative movement between the races of the bearing is positioned between two rings formed as axially-continuous extensions, integral or otherwise, of the bearing races. Where the rings are formed separately they are connected directly to the races with abutting radial surfaces. These ring-like extensions can have external axial surfaces, coplanar with the external axial surfaces of the races, or inner axial surfaces parallel to the axial surfaces of the races. In other known bearing assembly constructions the axial dimensions of integral bearing races are unequal thereby providing an axial extension portion of one race in relation to the other. The term "axial extension" is intended to refer to these configurations. In some of the constructions described in the aforementioned specifications, a disc-like component is supported by the axial ring-like extension of the movable race while the sensing means which senses the passage of this component is supported by the axial ring-like extension of the stationary race. In the construction with bearing races of dis-similar axial dimensions a disc-like component is again supported by the extension portions of one of the races, which is intended to move, to bring the component into a closed space where sensing occurs. A general object of the present invention is to provide improved forms of bearing assemblies and sensing means of the general type described in the aforementioned specifications.

According to the present invention there is provided a bearing assembly comprising first and second relatively movable bearing races, a component mounted to, or associated with, the first race for movement therewith and sensing means mounted to, or associated with, the second race for sensing the relative movement of said component in relation to said second race, wherein at least the sensing means is disposed predominantly within a zone bounded by an axial projection of the radially outermost surface of the bearing races or by radial projections of the axially outermost surfaces of the bearing races, the sensing means operates in the manner as defined hereinafter to produce an electrical signal indicative of the relative movement between the races and said component is supported in its operating position for direct movement with the first race at least partly by an axial surface of the first race, other than an axial extension of the first race, or by the provision of means

abuttingly-locating the component axially between radial surfaces.

The expression "operates in the manner as defined hereinbefore or hereinafter" means the following:

By the energization of an inductive element to create a magnetic field and by the detection with the aid of the inductive element of the magnetic field as influenced by the passage of the component movable with the first race.

The present invention also provides a bearing assembly comprising first and second relatively movable bearing races, a component mounted to or associated with the first race for direct movement therewith and sensing means mounted to or associated with the second race for sensing the relative movement of said component in relation to said second race, wherein at least the sensing means is disposed predominantly within a zone bounded by an axial projection of the radially outermost surface of the bearing races or by radial projections of the axially outermost surfaces of the bearing races, the component is mounted in its operating position directly to the first race to locate at least partly on an axial surface of the first race, other than an axial extension of the first race, or is supported to the race by means abuttingly-locating the component axially between radial surfaces and the sensing means operates by detecting electromagnetic radiation influenced in a transmissive or reflective sense by the passage of said component or by detecting variation in electrical capacitance brought about by the movement of said component to produce an electrical signal indicative of the relative movement between the races.

In accordance with certain embodiments of the invention the sensing means can be mounted in or supported by carrier means or housing which is arranged at one side of the bearing races and is preferably detachably secured thereto. In other embodiments the carrier means or housing can be disposed radially inwards or outwards of the bearing races. Thus according to the application or use, the available space can be utilized as appropriate.

The sensing means may take a variety of forms.

The sensing means can provide either a digital or an analogue signal, or both, indicative of speed and/or position.

The invention may be understood more readily, and various other features of the invention may become apparent, from consideration of the following description.

Embodiments of the invention will now be described, by way of examples only, with reference to, the accompanying drawings, wherein:-

Figure 1 is an exploded perspective view of part of a first assembly employing a rolling element bearing and sensing means constructed in accordance with the invention;

Figure 2 is an exploded perspective view of part of a second assembly constructed in accordance with the invention;

Figure 3 is a circuit diagram depicting one form of sensing means for use in assemblies constructed in accordance with the invention;

Figure 4 is a circuit diagram depicting a modified form of sensing means for use in assemblies constructed in accordance with the invention;

Figures 5 to 9 are diagrammatic representations of other bearing assemblies constructed in accordance with the invention;

Figure 10 is a diagrammatic side view of another rolling element bearing assembly constructed in accordance with the invention;

Figures 11 to 14 are sectional side views of further bearing assemblies constructed in accordance with the invention;

Figure 15 is a diagrammatic side view of a portable tachometer instrument constructed in accordance with the invention;

Figure 16 is a schematic block diagram of a digital to analogue converter which can be used with the sensing means of assemblies constructed in accordance with the invention;

Figure 17 is a schematic block diagram of a modified form of the sensing means shown in Figure 3 which may be employed in or with the assemblies constructed in accordance with the invention;

Figure 18 is a schematic block diagram of a further sensing means with a capacitive sensor which may be employed in or with the assemblies constructed in accordance with the invention;

Figure 19 depicts a configuration for the capacitive sensor provided in sensing means for use with assemblies constructed in accordance with the invention;

Figure 20 is a schematic block diagram of a modified form of the sensing means shown in Figure 18 which may be employed in or with the assemblies constructed in accordance with the invention;

Figure 21 is a diagrammatic side view of part of one form of capacitive sensor for use with assemblies constructed in accordance with the invention;

Figure 22 is a diagrammatic end view of the part of the sensor shown in Figure 21;

Figure 23 is a diagrammatic side view of part of another form of capacitive sensor for use

with assemblies constructed in accordance with the invention;

Figure 24 is a diagrammatic end view of the part of the sensor shown in Figure 23;

Figure 25 is a schematic diagram depicting another form of capacitive sensor;

Figure 26 is a diagrammatic side view of another bearing assembly made in accordance with the invention;

Figure 27 is a diagrammatic side view of an alternative arrangement with sensing means for use in a bearing assembly;

Figures 28 and 29 are diagrammatic side view of further bearing assemblies made in accordance with the invention;

Figure 30 is a view of part of another sensing means usable in a bearing assembly;

Figure 31 is a view of a modified form of disc for use in the sensing means of a bearing assembly;

Figure 32 and 33 are partial view of ring components for use in the sensing means of a bearing assembly;

Figure 34 is a diagrammatic side view of a modified form of sensing means for a bearing assembly;

Figure 35 is a diagrammatic side view of another bearing assembly made in accordance with the invention; and

Figure 36 is a perspective view of part of a further sensing means for a bearing assembly.

Before describing the various assemblies and devices which embody the present invention it is worth emphasizing at this stage in all cases where bearings are used in the assemblies these bearings can be entirely conventional and are unmodified per se or only modified in minor respects.

As shown in Figure 1, a conventional rolling-element bearing 1 has an inner race 10, an outer race 11 and rolling elements, in this case balls 12, therebetween. For convenience, the conventional cage for retaining and spacing the balls 12 is omitted from the drawing and it is assumed for the purposes of illustration that the inner race 10 is rotatable while the outer race 11 is stationary.

In accordance with the invention electronic sensing means is provided for sensing relative movement between the races 10, 11 thereby to provide a signal directly indicative of rotary speed. The sensing means in this embodiment employs a circuit as depicted in Figure 3 and is carried and housed by a component in the form of a carrier ring 13 mounted at the side of the bearing 1. The ring 13 is mounted to the outer race 11 and in this illustrated assembly the ring 13 has a recessed shoulder 13' at its inner side which frictionally engages with corresponding flanks 13" of the outer race 11 as a press fit. As an alternative the ring 13 can be adhesively bonded, or keyed, or clamped, e.g., with screws, to the race 11. A further recess 13A beneath the shoulder 13' of the ring 13 accommodates a further component in the form of a toothed disc 14 which is designed to co-operate with the sensing means but which does not contact the ring 13. The toothed disc 14 has a flange 15 which is frictionally engaged as a press-on fit with the outer face 15' of the inner race 10. The electrical components of the sensing means, described hereinafter, are collectively designated 16 in Figure 1 and are supported by a printed circuit board 17 conveniently of annular or part annular shape. The printed circuit board 17 is itself mounted in the ring 13, which acts as a housing therefor, in the position denoted by dotted lines 17'. The ring 13 can be a moulded plastics component, preferably made from an epoxy resin. The sensing means includes an inductive sensor or probe 9 in the form of an inductive coil wound onto a ferrite core or rod 18 also mounted to the printed circuit board 17. The ferrite rod 18 adopts the position denoted by dotted lines 18' in the ring 13 and projects parallel to the axis of rotation of the bearing 10, 11 to terminate closely adjacent the teeth 19 of the disc 14. In general, the movement of the teeth 19 in spaced succession as the disc 14 rotates with the race 10 cause discontinuity sensed by the sensor or probe 9. In this case the disc 14 is an integral metal component with at least the teeth 19 being made from an electrically conductive material in which eddy currents can be produced locally of the rod 18 by an alternating current set up in the inductive coil by an oscillator of the sensing means. The discontinuity produced by the teeth 19 and the gaps therebetween successively moving past the rod 18 give rise to changes in a parameter of the circuit of the sensing means which changes are detected to provide a signal directly indicative of rotary speed.

The operation of the sensing means will be described in more detail in conjunction with Figure 3.

As shown in Figure 3 the circuit of the sensing means comprises an R.F. tuned oscillator with a single N-P-N transistor TR1 having its emitter connected via resistors RL, RL2, to a negative d.c. voltage. A capacitor CL is connected in parallel with the resistor RL2. An output signal is generated across the capacitor CL and is taken off via an output OL. A tuned sub-circuit is composed of a centre-tapped coil T1, T2 wound onto the ferrite core or rod 18 and capacitors C1, C2 connected in series between the collector and base of the

transistor TR1. The coil T1, T2 is connected in parallel with the capacitor C1 and has its centre tap connected to a positive d.c. voltage. A bias resistor R1 is connected between the base of the transistor TR1 and the positive d.c. voltage. The circuit is energized by the positive and negative voltage supplies which may be conveniently combined in a small electric cable C with the output OL. In one practical embodiment of the circuit the following components are utilized.

TR1	BC182 - National (Registered Trade Mark) Semiconductors	
RL1	47Ω ½ w	
RL2	820Ω ¼ w	
R1	100KΩ ¼ w	
T1	12 Turns	38 s.w.g. enamelled copper wire
T2	50 Turns	
Ferrite	Rod diameter 1.6 mm Rod Length 11.5 mm (overall) with or without a modified end portion with a chisel-like shape or a tapered, e.g., frusto-conical shape	
C1	2200 pF	
C2	100 pF	
C3	0.1 μF	
CL	0.22 μF	

Voltage supply - Typically 12v.

During operation, the circuit oscillates continuously at radio frequency to generate an alternating current in the inductive coil T1, T2 and eddy currents are induced in each tooth 19 as the latter moves across the axis of the rod 18. The alternate presence and absence of such eddy currents, corresponding to the alternate presence and absence of a tooth in the vicinity of the rod 18, produces reflected impedance changes in the collector load which produces a variation in the emitter current. This in turn, gives rise to a typical waveform of the type shown in Figure 3 as an output. For a particular spacing between the sensor 9 (18, T1, T2) and the teeth 19 of the disc 14 the waveform has a constant amplitude and if desired the pulsed or square output signal can be amplified and/or additionally processed and shaped to provide a series of pulses the frequency of which directly represents the rotational speed of the inner race 10. The circuit can be modified as depicted by chain-dotted lines with the components RL2, CL remote, from the sensing means and the output provided on a pair of leads S. The digital signal produced or derived from the sensing device can be utilized in a variety of ways, for example in a comparator fashion, to provide, in other related embodiments, a measure of angular acceleration or position for example. In one embodiment, a direct count and visual display of the number of pulses occurring in a specific time period can be produced. In a modified sensing device, described in outline hereinafter in connection with Figure 18, the affect of the teeth 19 on the operation of the oscillator may be detected as a change in phase rather than a change in impedance but nonetheless a digital signal can still be produced which represents rotary speed. Figure 4 depicts a modified circuit where like reference numerals denote like parts to Figure 3. The circuit of Figure 4 has an additional line driver stage 16′ fed by the basic oscillator 16. In a practical embodiment of the line driver circuit the following additional components were utilized:-

L1	22 H SC30/22
R2	1K ¼w
R3	1.2 KΩ¼w
R4	10KΩ ¼w
R5	10KΩ ¼w
R6	820KΩ ¼w
R7	820Ω ¼w
R8	1KΩ ¼w
R9	18Ω ½w
R10	10Ω ¼w
C4	0.047 μF
C5	6.8 μF
C6	0.22 μF
A1	LM111H National Semiconductors

TR2-	BC182 - National Semi conductors
TR3-	2N2222A - National Semi conductors
TR4-	2N2222A - National Semi conductors
TR5 -	2N2222A - National Semi conductors

In the assembly shown in Figure 2 like reference numerals are used to denote the same features as the assembly described and illustrated in Figures 1 and 3. In contrast to Figure 1 however the assembly of Figure 3 has the orientation of the rod 18 radial to the axis of rotation instead of parallel thereto. The disc 14 can be a shaped pressed-on metal, e.g., steel, structure 14A or a more simple plane ring component 14B produced by powder metal technology with projections or teeth 19 around its periphery. The particular orientation of the sensor 9 on relation to the teeth 19 is not particularly critical and angular dispositions can be adopted.

In one specific notable application of the invention the disc 14 and the ring 13 with the sensing means can be mounted to a wholly standard vehicle wheel bearing thereby providing a signal for a digital tachometer. If, for example, a digital display of revs/minute is required the disc 14 can have 60 teeth and a digital counter can count the number of output pulses produced by the sensing means over a one-second period.

In this case the inner race 10 would be stationary on the wheel hub while the outer wheel race 11 would rotate and the positions of the ring 13 and the disc 14 would preferably be reversed. With a front wheel drive vehicle, however, where the inner race 10 rotates and the outer race 11 is stationary the arrangement as illustrated can be adopted without alteration.

The sensing means as described may also be incorporated or used with a variety of other forms of bearings. Figures 5 to 10 depict examples of other forms of bearings where again like reference numerals denote the same or analogous components to Figures 1 to 4. Thus Figure 5 has a rotating inner race 10 and balls 12 as rolling elements but the outer race 11 is here in angular contact with the balls 12. Figure 6 represents a thrust bearing with load plates 20, 21. Figure 7 represents a roller bearing, Figure 8 a spherical bearing and Figure 9 a plain bearing. In all cases provision of the separate disc 14 and the ring 13 and the sensing device does not affect the design and operation of the bearings which can be quite standard.

In some applications the movement which is to be detected is especially rapid and a disc or rack with a large number of teeth, such as is illustrated, would cause the circuit to reach the limits of its response time in relation to the transitions producing the square wave. In these cases it is easy to use a component with just one tooth or a few teeth. For example, with a high speed rotary bearing a single tooth on the periphery of the disc 14 would produce one pulse per revolution. The use of toothed components and metal components is also not essential to the operation of the sensing means as described. It is only necessary to produce some discontinuity in the path of relative movement of a conductive or magnetic influence sufficient to affect the operation of the oscillator of the sensing means to provide the necessary detecting function. In one simple alternative arrangement, especially applicable to rotary bearings, a plastics ring may carry a series of discrete discs, or slugs, or other bodies, of metal, such as brass or aluminium, seated into holes or bonded to the ring and these metal bodies would act in an analogous fashion to the individual teeth described hereinbefore. In the case of high speed bearings again a single metal body on the plastics device may suffice. Instead of metal bodies one or more discrete magnets can be carried by the plastics ring and here there would be flux linkage between the individual magnet or magnets and the inductive coil T1, T2 of the sensing device. Otherwise the operation and construction of the sensing device and the assemblies utilizing the same can be as described above.

Although the use of the printed circuit board and the carrier ring 13 for the sensing device is quite practicable and has certain advantages with small scale production other methods of construction for the sensing device can be adopted. Thus in one method the individual electrical components of the sensing device are wired in a jig mould and the mould filled with plastics, such as epoxy resin, preferably by injection moulding to encapsulate the electrical components and form a permanent housing (c.f. the ring 13) therefor. In another method of construction a flexible printed circuit carrying the electrical components is disposed around a desired bearing circumference and then a plastics material is again used to encapsulate all the components. One advantage of this technique would be that a standardized printed circuit board can be used to provide a variety of sizes of housings to match a range of bearings.

The circuit of Figure 3 or 4 is eminently susceptible to an integrated circuit conveniently encapsulated or merely embedded in a structure such as the carrier ring 13. The circuit can also be constructed by thick or thin film techniques where the circuit components are deposited on substrates such as glass or ceramic forming part or all of a structure such as the

carrier ring 13. Again a standard circuit can be used for a variety of different sized carrier or housing components. Even with standard electrical components the device can be compact and additional electronic circuits and devices can easily be incorporated into the bearing assembly.

Figure 10 depicts another rotary bearing employing a sensing device here mounted in another fashion. The bearing as depicted has a conventional cage 23 locating the balls 12 between the inner race 10 and the outer race 11. A conventional flexible seal 30 is located at one side of the bearing between the races 10, 11 and is fitted to the outer race 11. A flexible cover 32 complementary to the seal 30 and incorporating an integrated circuit chip 31, for example, or some other means embodying the sensing means or circuit of Figure 3 or 4 except for the coil, is located at the other side of the bearing. The cover 32 can also be fixed to the outer race if desired but in any event remains stationary and also performs a sealing function. A toothed ring or analogous component 34 is again mounted to the inner race 10. The ferrite core or rod 18 carrying the electrical coil extends radially to intersect the path of movement of the discontinuity of the component 34 and the rod 18 is mounted to the cover 32.

In the embodiment illustrated in Figure 11 a bearing assembly has a sleeve 49 with a pair of O-rings 45 on its inner surface. The sleeve 49 has a flange 50 at one end which locates a toothed disc 14. A sensor unit or housing 42 is arranged concentrically with the sleeve 49. A standard rolling element bearing 1 represented schematically and having inner and outer rings or races (e.g., as in Figure 1) is disposed between the sleeve 49 and the housing 42 to render these components relatively rotatable. A spacer 44 locates between the bearing 1 and the disc 14. The housing 42 contains sensing means which may be constructed as described and illustrated in Figure 3 or 4. The components of the sensing means are again mounted on a printed circuit board 17 and the ferrite rod or probe 18 projects across the external periphery of the toothed disc 14. A dust shield 43 is snap-fitted between the flange 50 of the sleeve 49 and a recessed shoulder in the housing 42. The assembly as described can be mounted onto a shaft or spindle 41 which projects into or through the sleeve 49. The housing 42 can be held stationary by any suitable means and rotation of the spindle 41 moves the teeth of the disc 14 passed the probe 18. The sensing means then operates to produce a rotary speed-indicative signal as described.

In the embodiment depicted in Figure 12, like reference numerals are used to denote like parts to Figure 11. In the Figure 12 embodiment, an adaptor 29 is used to rotatably connect the sleeve 49 to a rotary part (not shown) of generally smaller diameter than the shaft of spindle 41 of Figure 1 and the O-rings 45 are omitted. A rod 36 is used to engage with a bracket or the like (not shown) thereby to lock the housing 42 in a stationary position. A detachable cover 38 is provided to provide access to the housing 42.

In the embodiment depicted in Figure 13 again like reference numerals are used to denote like parts to Figures 11 and 12. In contrast to the assemblies of Figure 11 and 12 however, the stationary housing 42 of Figure 13 is provided at the inside of the assembly and is held by a sleeve 51. The toothed disc 14 here has the teeth on its inner periphery for movement passed the probe 18 of the sensing means. The toothed disc 14 is mounted to a flanged cylindrical member 52 which rotates relative to the housing 42 and the sleeve 51 which are preferably held stationary. As illustrated, a cylindrical part 53, which may be the hollow end portion of a shaft or the like, is engaged with the member 52 so that the sensing means provides a signal indicative of the rotation of the part 53.

Figure 14 depicts a modified assembly similar to Figures 10 and 11 and particularly designed for use with speedometer cables of motor vehicles. In Figure 14, like reference numerals again denote like parts to the previously-described embodiments. A structural member 60 normally part of a gearbox, contains a rotatable coupling 61. The member 60 has an external threaded region 60′ which normally receives an internally-screw threaded region 62′ of a conventional speedometer cable end cap 62. The inner square-sectioned rotatable core 63 of the speedometer cable would normally locate directly with the coupling 61. In the illustrated assembly, however, the core 63 is extended to project through the basic bearing 1 and engages in a square piercing 64 in the sleeve 49. The housing 42, containing the sensing means, engages with two cylindrical bodies 65, 66. The body 65 is threaded internally to mate with the threaded region 60′ of the member 60 while the body 66 is threaded externally to receive the threaded region 62′ of the cap 62. Thus the bodies 65, 66 hold the housing 42 stationary. The rotary movement of the coupling 61 drives the core 63 to operate the speedometer in the usual manner. In addition, the core 63 rotates the sleeve 49 and the toothed disc 14 and the sensing means produces a signal indicative of this rotary speed.

It is desirable to provide the body 65 with a cooling fin 68 and to manufacture this body 65 and preferably also the body 66 from a material such as an aluminium or duralumin to act as a heat shield for the housing 42 and the electronic components therein.

In the assemblies as described and illustrated in Figures 11 to 14 the electrical cables or leads denoted by dotted lines 40 and connecting to the sensing means can be taken out at any convenient region and not necessarily in the position as illustrated.

Figure 15 depicts a portable tachometer instrument which employs an assembly of the type shown in Figures 11 and 12. This assembly is mounted at one end of a housing 90, conveniently made of synthetic plastics. A cap 91 at this end of the housing 90 has a central bore 96 and a connector 92 here in the form of a conical member projects through the bore 96. The connector 92 is conveniently detachably fitted, e.g., by a push-fit into the sleeve 49 which is rotatably secured to the inner race of the bearing 1. The connector 92, which can be replaced to suit a particular application, can be mated to any rotatable mechanism or device and then the rotation of the toothed wheel or disc 14 produces the speed indicative signal as before. The speed-indicative signal is processed by means in the interior 97 of the housing 90 and displayed as a digital read-out 93 visible from the side of the housing 90. The power for the sensing means 16 can be provided by re-chargeable batteries (not shown) mounted in a space 94 of the housing 90. A socket 95 at the opposite end of the housing 90 serves to connect the batteries to a charging unit or supply.

As mentioned previously additional electronic circuits and devices can be provided to process the waveform produced by the basic circuit of Figure 3.

Figure 16 depicts an example of an additional processing circuit in the form of a digital to analogue converter for the sensing means of Figure 3 or 4. In Figure 16, the oscillator and detector circuit of Figure 3 or 4 is designated 70 and the output therefrom is optionally fed through an amplifier and shaper 71 to drive a monostable circuit 72. The sharp square wave digital output produced by the circuit 72 has a frequency representing motion and the output of the circuit 72 is fed to an integrator 73 which provides an analogue voltage the amplitude of which is proportional to motion. The analogue output from the integrator 73 is finally amplified by an amplifier 74.

Figure 17 represents an alternative form of detecting operation for producing a waveform from the sensing means related to the rotary motion or position in which the change in phase in the alternating current in the oscillator is sensed. In Figure 17 the oscillator of Figure 3 or 4 denoted 70 feeds a phase shift detector 80 which produces a pulsed waveform related to speed and this waveform is amplified by amplifier 81 and shaped by shaper 82 to provide a more regular square waveform.

In other embodiments of the invention the inductive sensor 9 is replaced by a capacitive sensor or probe. Otherwise however the assemblies described hereinbefore can be adopted without extensive modification. The basic circuit of Figure 3 can be re-arranged so that C1 becomes the capacitive sensor and the coil T1, T2 now assumes a non-sensing function. One plate of the capacitive element C1, now constituting the capacitive sensor, could then be connected to the tuned circuit while the other plate would be formed periodically for example, by the teeth 19 of a disc 14 or by the rolling elements 12 or by some other means. The operational change in the circuit of Figure 3 caused by the change in capacitance of the sensor can be detected, for example as a frequency or phase change in the manner described to produce the speed or position indicative signal. Instead of being incorporated as a frequency-determining element of the oscillator, the capacitive sensor can be used to modify the output from a free-running fixed frequency oscillator and Figure 18 is a block diagram depicting one example of this arrangement. In Figure 18 an oscillator 75, produces a signal of say 10MHZ and, feeds a network composed of a resistor 76 and a capacitive sensor 77 which varies in capacitance in accordance with speed or position. The capacitive sensor 77 feeds a detector and amplifier 78 which produces an output signal of the type shown. Figure 20 depicts another arrangement wherein an oscillator 75 feeds a monostable device 70 and a logic device 83. The device 79 employs the capacitive sensor 77 to vary the width of its output pulses. The device 83 feeds a flip-flop device 84, the output of which is buffered by a buffer device 85. The monostable device 79 is triggered by a clock 86. The output from the device 79 is more than 1 clock period with the sensor 77 at its maximum value and less than 1 clock period with the sensor 77 at its alternate minimum value. The logic device 83 is designed to trigger the flip flop device 84 successively according to the length of the output pulse from the device 79. The device 84 thus produces a series of pulses with a repetition rate dependent on speed or position. The capacitive sensor 77 can be incorporated in a bearing assembly as described and exemplified hereinbefore. This necessitates constructing the sensor 77 with at least one moving component and at least one stationary component. To avoid problems in making electrical connection to the movable component the configuration depicted in Figure 19 can be adopted which is equivalent to two capacitors in series. The centre plates of the series capacitors designated 59 can then be the movable component to which no electrical connection is made. The outer plates of the series capacitors designated 67, 69 can then be static components.

In general, the capacitive sensor 77 can be formed by axial concentric tubes or radial flat

discs. The former configuration has the advantage that the capacitance variations can be maintained within close limits by relying upon the usual excellent tolerances of the bearing 1. Figures 21 and 22 represent schematically an arrangement where a disc 14, analogous to the toothed disc 14, of the other embodiments and made for example from plastics material has a series of interconnected plates 59 on its opposite side faces. The disc 14 rotates with one of the races 10, 11 of the associated bearing and can be mounted as described above. The plates 59 on either side of the disc 14 are also interconnected by means extending through the disc 14. Conveniently, the disc 14 can be a double-sided printed circuit board. A ring or housing 54 receives the disc 14 between complementary plates 67, 69 and the ring or housing 54 may be mounted in the manner of the analogous structure 13, 42 described hereinbefore. The electronic circuit associated with the capacitive sensor thus-formed can be built into the housing 54. Alternatively, two separate stationary discs forming or carrying the plates 67, 69 can encompass the disc 14 and the electronic circuitry can be separate and remote. The arrangement shown in Figures 23 and 24 has projections forming plates 67, 69 provided at the inner face of the housing 54 and the disc 14 has associated projections forming plates 59 formed at its outer peripheral surface. Conveniently the plates 67, 69, 59, are integral with their carrier bodies 14, 54 although separate plates can be fixed to the carrier bodies 14, 54. In any event the electronic circuitry can be separate and remote. Another type of capacitive sensor is depicted in Figure 25. This sensor consists of a pair of concentric components in the form of half-cylinders or rings 46, 47 designed to relatively rotate about one another. An analogous construction (not illustrated) utilizes a pair of spaced shaped vanes, which may be semi-circular, as the components 46, 47. The capacitance formed by utilizing the components 46, 47 as the plates of the capacitive sensor varies according to the relative rotational position prevailing and changes progressively between maximum and minimum values. An analogue signal can thus be generated by an oscillator which varies according to the angular position or rotation as desired. Where a digital rotational speed indicative signal is desired the analogue signal can be converted into an equivalent digital signal but where angular resolution is of interest the analogue signal can be used directly.

Instead of employing sensing means with inductive or capacitive sensors as described, the various assemblies as illustrated and described in Figures 1 to 9 and 11 to 17 can employ other forms of sensing means and sensors as will now be described.

As shown in Figure 26, two bodies 87, 88 are respectively mounted or located to the outer and inner races 11,10 of a ball or roller element bearing 1. The bodies 87, 88 can adopt a variety of shapes and/or different positions and Figure 26 is merely illustrative. The main criterion is for the bodies 87, 88 to move relatively in proportion, direct or otherwise, to the motion to be sensed. It is assumed in this arrangement that the body 87 and the outer race 11 are stationary while the inner race 10 and the body 88 rotate. Where the race functions are reversed it is preferable to reverse the bodies 87, 88 so that the body 88 moves relative to the body 87. Preferably seals 30 protect the bearing and the sensing means. In this type or class of embodiment the body 87 carries or is provided with means emitting and receiving electromagnetic radiation, more usually visible light, although infra-red, ultra-violet or microwave wavelengths can be utilized. The body 88 carries or is provided with means for modifying the emitted radiation in accordance with its speed or position.

In the particular embodiment represented by Figure 26, the body 87 supports a collection of optical fibres mounted in a ferrule 89 to face with their free ends the body 88. The fibres are sub-divided into a group 97 leading to a source 99 of radiation or light and a group 98 leading to a radiation detecting means 100. In this mode of operation, the body 88 has a series of spaced reflecting surfaces designed to reflect the radiation emitted from the fibre group 97 back to the fibre group 98 for detection. As the reflecting surfaces move past the body 87 the emitted radiation is alternately reflected and not-reflected, e.g., absorbed or diffused, so that the detecting means 100 produces a pulsed or digital signal with a repetition frequency proportional to speed or position. This source 99 may be an L.E.D., a tungsten lamp or a laser, for example, while the receiving or detecting means 100 can at least include a photocell, a photo transistor or a photo diode for example.

Figure 27 depicts an arrangement which again employs a toothed disc 14 rotating with one of the bearing races. The teeth or projections 19 of the disc 14 here serve to alternately permit and obstruct the transmission of radiation across a gap 22 in a stationary housing 42 conveniently mounted in a similar manner to that depicted in Figures 12 or 13, for example. The reference numerals 99 and 100 again denote the radiation source and the receiving or detecting means and these may be local devices supported in the housing 42 or remote devices connected to optical fibres as in the Figure 26 arrangement. Instead of employing teeth, the disc 14 can have a series of holes, or windows to transmit the radiation. The disc 14 can also be wholly transparent or translucent and provided with a series of opaque regions. In a reflective mode, the disc 14 can have a series of mirror-like surfaces, e.g.,

chrome deposits on its side surface. The disc 14 may extend radially or parallel to the rotational axis or the disc 14 can form part of a shaped structure. Figures 28 and 29 depict assemblies employing the arrangement shown in Figure 27. Where the sensing means is to sense angular position rather than motion, the sensitivity of the detecting means 100 can be increased by utilizing several radiation receivers, such as groups of optical fibres or direct receivers, such as photocells, which are inclined as an array to the orientation of the holes or windows or other transmitting or reflecting regions of the disc 14 or the body 88. Figure 30 depicts an arrangement of this kind where the disc 14 has windows 115 therein and an array 117 of individual receivers 116 is positioned as shown. The total number of pulses produced for each revolution of the disc 14, and hence the associated bearing, can be increased considerably by logic circuits-typically up to 50,000 per revolution. It is also possible to produce a disc 14 with a number of separate series of transmitting or reflective regions. Thus Figure 31 shows separate concentric groups of different-sized apertures denoted 118, 119 and 120. The groups 118, 119, 120 may be associated with their own receivers and simultaneously coarse and fine grade signals can then be provided for different purposes if desired. Another form of disc 14 is provided with a large number of radial grating lines which intersect a radiation beam to modify the radiation as desired. This type of disc 14 would provide a sinusoidal response. In another construction, separate discs with radial grating lines provide a Moiré fringe pattern which is analysed to provide a signal indicative of position or motion.

Figures 32 and 33 depict simple ring components 24 which can be used with or as the body 88 in the type of assembly shown in Figure 26. In Figure 32, the ring 24 has a number of regular prismatic reflecting surfaces 25 on its exterior periphery which reflect the incident radiation as shown when in the correct orientation vis-a-vis the radiation emitter. The surfaces 25 need not be external and Figure 33 depicts a transparent ring 24 made, for example, from perspex, where the surfaces 26 on its inner periphery act as internal reflectors as shown. The surfaces 25, 26 of the rings 24 may extend radially to the axis of rotation or parallel to the axis of rotation. One of the bodies 87, 88 or both bodies 87,88 in the type of assembly shown in Figure 26 may have additional reflectors or collimating or focussing means to direct and transform the radiation as may be desired. Another ring construction usable in the assemblies has a series of lines or bands scored or etched into its surface to concentrate and/or interrupt the passage of transmitted and/or reflected radiation.

Figure 34 depicts an arrangement where a radiation emitter 101 and a radiation receiver 102 - which may be optical fibres connected to the source 99 and detecting means 100 as before – are entirely separate from the bearing assembly. A stationary body 103 having a reflective surface 104 directs radiation as shown to a series of reflective surfaces 105 of a body 106 which rotates for example with the outer race 11 of the associated bearing. The body 103 can be mounted to the stationary bearing race if desired. The reflective surfaces may be formed by making alternate light and dark bands within the body 106 and both bodies 103, 106 can be solid perspex rings. In this type of arrangement, the body 103 is not wholly essential and Figure 35 depicts an analogous arrangement where the single body 106 rotating with the race 11 has both reflecting surfaces 104, 105. It may be convenient to combine components of the sensing means with a seal for the bearing.

Figure 36 depicts another arrangement which employs a transparent ring 107 illuminated internally with the radiation emitter 101. The ring 107 has a series of fine lines 108 etched or scored into its outer periphery 110. The emitter 101 is positioned closely adjacent the axial face 109 of the ring 107 and the ring 107 rotates with the moving race of the bearing (not shown). The receiver 102 is positioned adjacent the periphery 110 of the ring 107 and the passage of the lines 108 which appear as concentrations of radiation, usually diffuse, are converted to a digital signal as before. Reference is directed UK patent application No 8102358 (Serial No 1604862) which relates to subject matter divided from this cognate application.

WHAT WE CLAIM IS:

1. A bearing assembly comprising first and second relatively movable bearing races, a component mounted to, or associated with, the first race for movement therewith and sensing means mounted to, or associated with the second race for sensing the relative movement of said component in relation to said second race, wherein at least the sensing means is disposed predominantly within a zone bounded by an axial projection of the radially outermost surface of the bearing races or by radial projections of the axially outermost surfaces of the bearing races, the sensing means operates in the manner as defined hereinbefore to produce an electrical signal indicative of the relative movement between the races and said component is supported in its operating position for direct movement with the first race at least partly by an axial surface of the first race, other than an axial extension of the first race, or by the provision of means abuttingly-locating the

component axially between radial surfaces.

2. A bearing assembly comprising first and second relatively movable bearing races, a component mounted to, or associated with, the first race for direct movement therewith and sensing means mounted to, or associated with, the second race for sensing the relative movement of said component in relation to said second race, wherein at least the sensing means is disposed predominantly within a zone bounded by an axial projection of the radially outermost surface of the bearing races or by radial projections of the axially outermost surfaces of the bearing races, the component is mounted in its operating position directly to the first race to locate at least partly on an axial surface of the first race other than an axial extension of the first race, or is supported to the race by means abuttingly-locating the component axially between radial surfaces and the sensing means operates by detecting electromagnetic radiation influenced in a transmissive or reflective sense by the passage of said component or by detecting variation in electrical capacitance brought about by the movement of said component to produce an electrical signal indicative of the relative movement between the races.

3. An assembly according to claim 2, wherein the sensing means is supported by carrier means connected directly to the second race.

4. An assembly according to claim 3, wherein the carrier means is connected to a side face of the second bearing race and the sensing means, carrier means and the component movable with the first race are collectively disposed within the zone bounded by an axial projection of the radially outermost surface of the bearing races.

5. An assembly according to any one of the claims 2 to 4 and further comprising display means for displaying a read-out indicative of the rotary speed of the first race and coupling means for selectively coupling the first race to an object, the rotary speed of which is to be displayed.

6. An assembly according to claim 2, wherein said component movable with the first race at least includes a first component of a capacitive sensor, the sensing means is supported by carrier means connected directly to the second race and wherein the sensing means further comprises oscillatory circuit means including a second component of said capacitive sensor and an inductive element which forms a tuned circuit with the capacitive sensor, the tuned circuit being directly energized by the oscillatory circuit means, relative movement between the bearing races causing relative movement between the components of the capacitive sensor with a corresponding variation in electrical capacity of the sensor and means for producing a signal dependent on said variation and indicative of said rotary movement of the first race.

7. An assembly according to claim 2, wherein said component movable with the first race at least includes a first component of a capacitive sensor, the sensing means is mounted to a side face of the second race and wherein said sensing means further comprises oscillator means and a second component of said capacitive sensor, relative movement between the bearing races causing relative movement between the components of the capacitive sensor with a corresponding variation in the electrical capacity of the capacitive sensor and means for producing a signal dependent on said variation and indicative of said movement of the first race.

8. An assembly according to claim 2, wherein said component movable with the first race at least includes a first component of a capacitive sensor, the sensing means is supported by carrier means connected to the second race, the sensing means further comprises oscillator means and a second component of said capacitive sensor, relative movement between the bearing races causing relative movement between the components of the capacitive sensor with a corresponding variation in the electrical capacity of the sensor, the output from the oscillator means being modified by the variation in the electrical capacity of the capacitive sensor and the detector means which produces a signal dependent on the modified output of the oscillator means and indicative of said movement of the first race.

9. An assembly according to claim 2, wherein said component movable with the first race is a disc formed with interconnected plates on its opposite side faces constituting a first component of a capacitive sensor, the sensing means is carried by carrier means connected to the second race and which has further plates complementary to the plates of the disc and adjacent said plates, the further plates constituting a second component of the capacitive sensor, relative movement between the bearing races causing relative movement between the components of the capacitive sensor with a corresponding variation in the electrical capacity of the capacitive sensor, the sensing means further comprises oscillator means modified by the variation in the electrical capacity of the capacitive sensor and signal-producing means which produces said signal dependent on said variation and indicative of said movement of the first race.

10. An assembly according to claim 2, wherein said component movable with the first

race is a hollow member with plate-like formations on a peripheral surface forming a first component of a capacitive sensor, the sensing means is carried by carrier means connected to the second race and which has further plate-like formations complementary to the plate-like formations of the hollow member and adjacent the latter, the further plate-like formations constituting a second component of the capacitive sensor, relative movement between the bearing races causing relative movement between the components of the capacitive sensor with a corresponding variation in the electrical capacity of the capacitive sensor, the sensing means further comprises oscillator means modified by the variation in the electrical capacity of the capacitive sensor and signal-producing means which produces said signal dependent on said variation and indicative of said movement of the first race.

11. An assembly according to claim 8, wherein the output from the oscillator means is amplitude modulated by the variation in electrical capacity and the detector means senses the amplitude modulation.

12. An assembly according to claim 8, wherein the variation in electrical capacity serves to alter the width of logic pulses representing the oscillator output and the detector means produces a series of corresponding signal pulses with a repetition rate dependent on said variation.

13. An assembly according to claim 8, wherein the first component of the capacitive sensor is electrically equivalent to the connected plates of two series capacitors and the second component is electrically equivalent to the outer plates of the series capacitors.

14. An assembly according to claim 2, wherein the sensing means includes electro-magnetic- radiation energy emitting means, said component movable with the first race serves to influence the radiation emitted by said emitting means and the sensing means further includes means for receiving radiation influenced by said influencing means and for producing said signal.

15. An assembly according to claim 14, wherein the component movable with the first race serves to influence the emitted radiation by reflection and the sensing means and the component are collectively disposed predominantly within a boundary defined by a lateral projection of the radially outermost surface of the bearing races.

16. An assembly according to claim 14, wherein the component movable with the first race serves to influence the emitted radiation by transmission and the sensing means and the component are collectively disposed predominantly within a boundary defined by a lateral projection of the radially outermost surface of the bearing race.

17. An assembly according to claim 14, wherein the component movable with the first race serves to influence the emitted radiation by transmission and the sensing means and the component are collectively disposed predominantly within a zone bounded by radial projections of the axially outermost surface of the races.

18. An assembly according to claim 14, wherein the component and the sensing means are collectively disposed predominantly within a zone bounded by radial projections of the axially outermost surface of the races.

19. An assembly according to claim 14, 15 or 18 wherein the arrangement is such that radiation is reflected along a path non-parallel to the axis of movement between the races.

20. An assembly according to claim 14, 15, 18 or 19, wherein the arrangement is such that the radiation is reflected a plurality of times to reverse direction parallel to the axis of movement between the races.

21. An assembly according to any one of claims 14, 15, 18 or 19, wherein the influencing component is a body with a series of spaced radiation-reflecting surfaces separated by non-reflecting surfaces.

22. An assembly according to claim 14, 15, 18, 19 or 20, wherein the influencing component has prismatic reflecting surfaces.

23. An assembly according to claim 14, wherein the influencing component is a body provided with grating lines.

24. An assembly according to claim 14, wherein the sensing means is supported by carrier means fixed to a side face of the second race.

25. An assembly according to claim 14, wherein the sensing means and the influencing component are collectively disposed within boundaries defined by axial projections of the radially innermost and outermost surfaces of the bearing races.

26. An assembly according to claim 14, wherein the influencing component is a radiation-transmitter ring provided with lines on an exterior surface, the emitting means serves to pass radiation into the ring and the receiving means is positioned to receive radiation from said exterior surface.

27. A portable tachometer employing an assembly according to any one of the preceding claims.

28. A portable tachometer substantially as described with reference to, and as illustrated in, Figure 15 of the accompanying drawings as modified by any one of the

Figures 18 to 36 of the accompanying drawings.

29. An assembly substantially as described with reference to, and as illustrated in, any one of Figures 1 to 17 of the accompanying drawings as modified by Figures 18-36 of the accompanying drawings.

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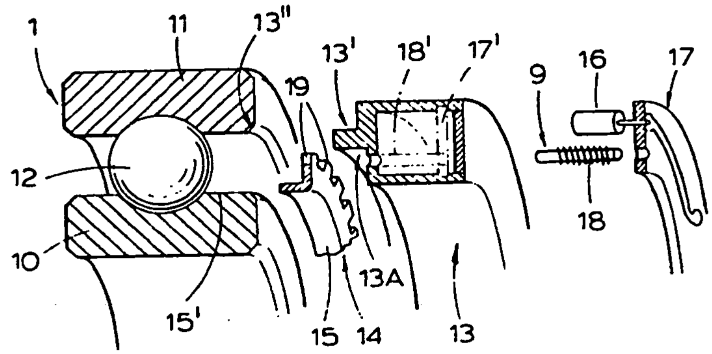
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Fig.1

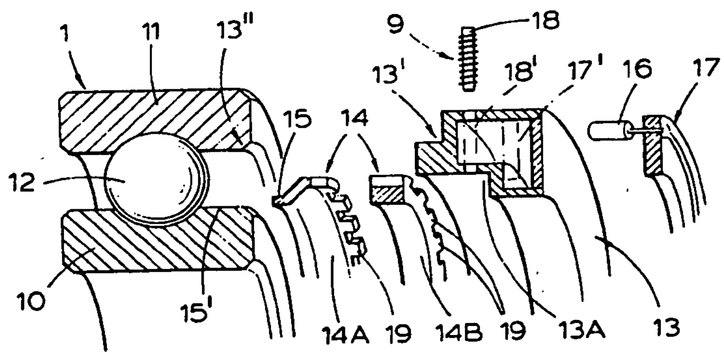
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Fig.2

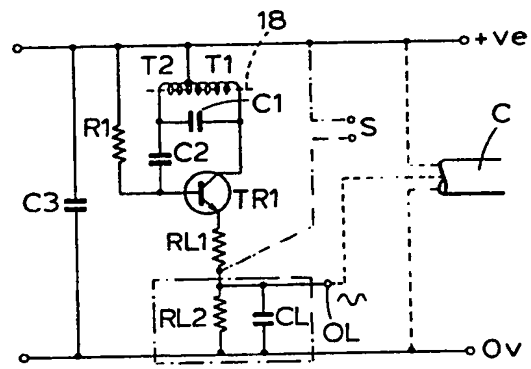
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Fig.3

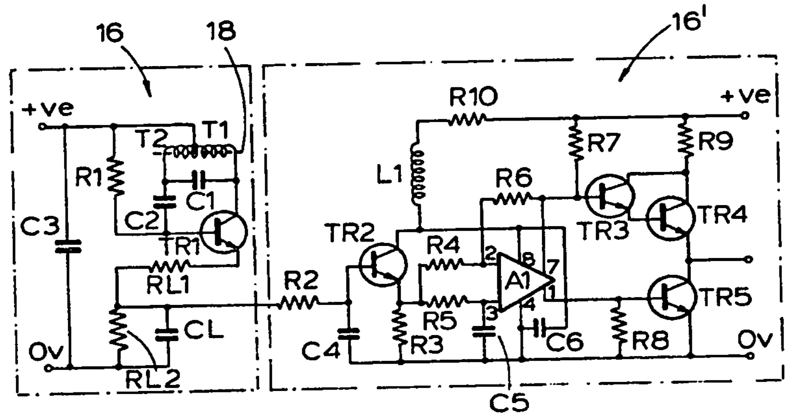
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Fig.4

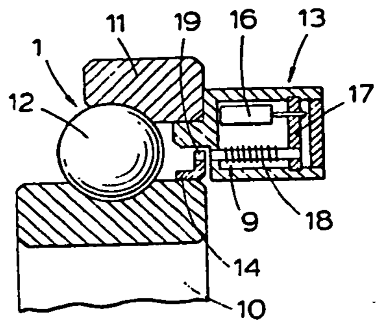

Fig.5

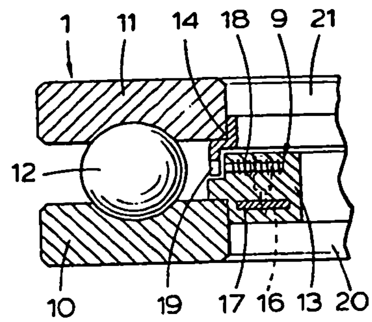

Fig.6

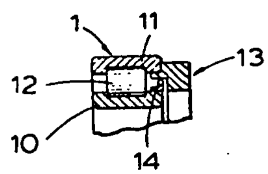

Fig.7

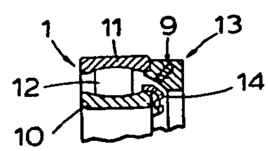

Fig.8

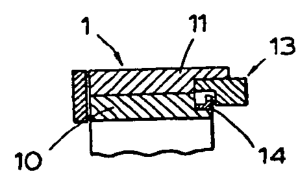

Fig.9

1604861 COMPLETE SPECIFICATION

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Sheet 4

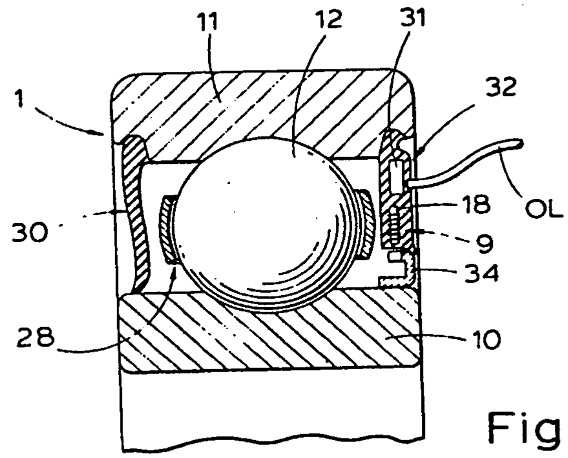


Fig.10

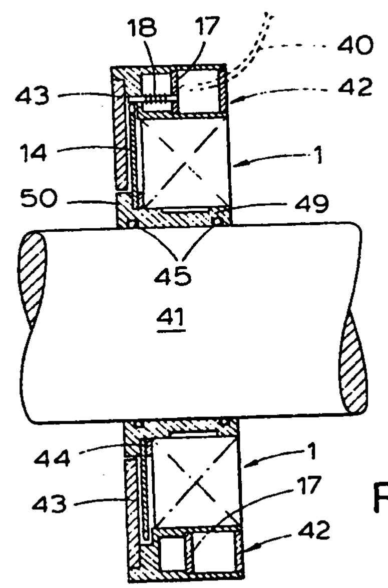


Fig.11

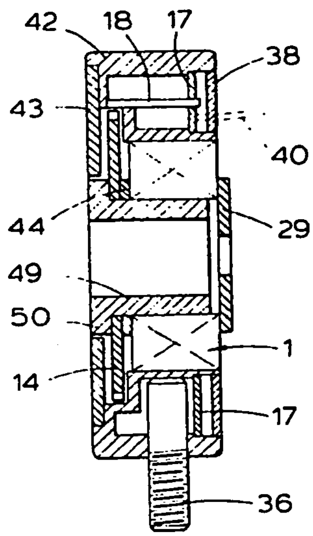


Fig. 12

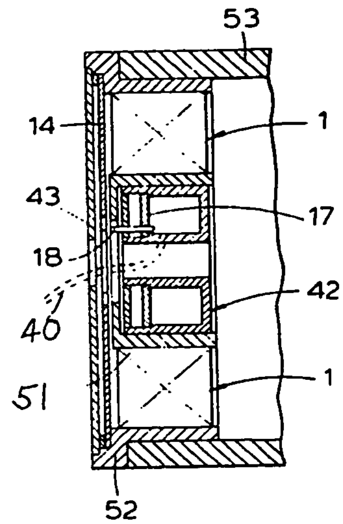


Fig. 13

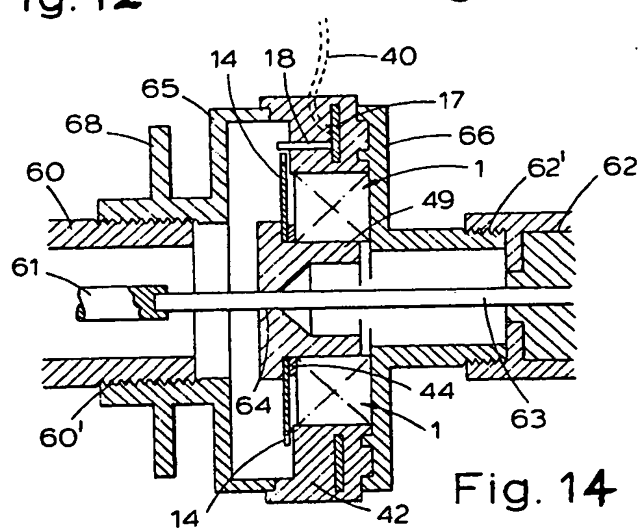


Fig. 14

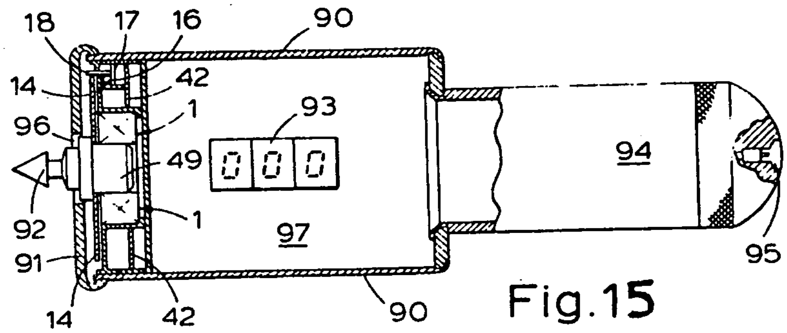


Fig.15

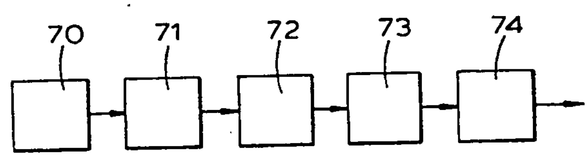
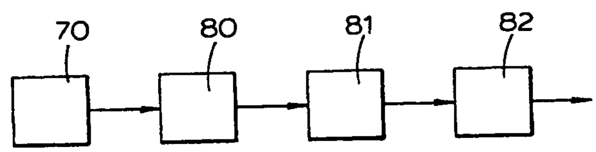


Fig.16



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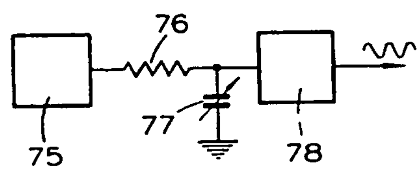

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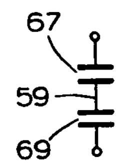

Fig.19

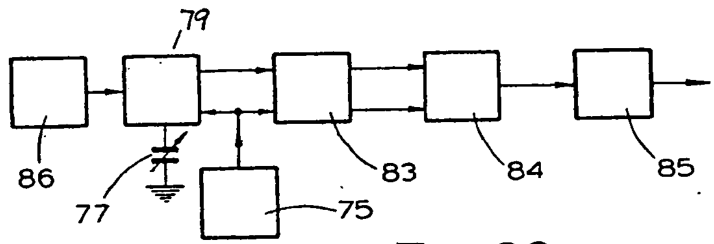

Fig.20

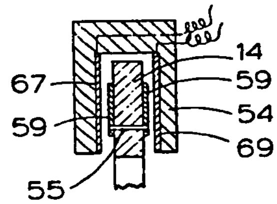

Fig.21

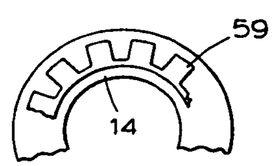

Fig.22

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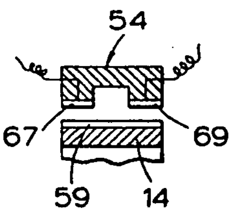

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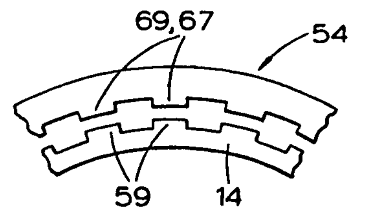

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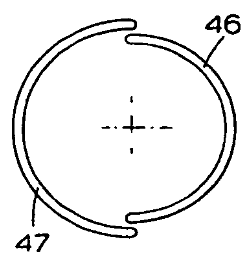

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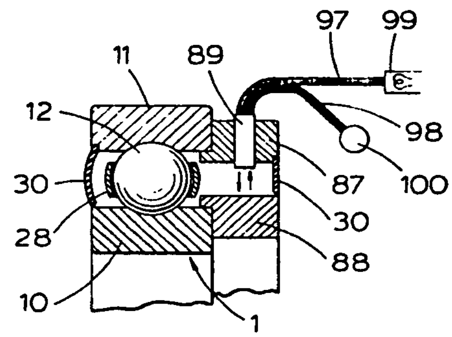
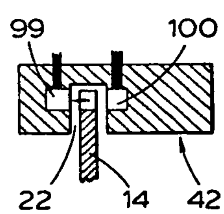


Fig.26



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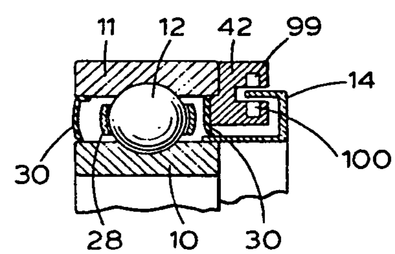
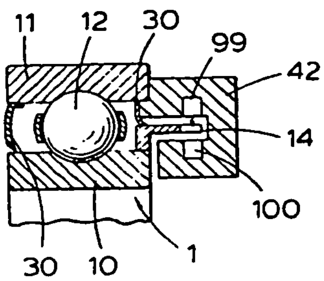


Fig. 28



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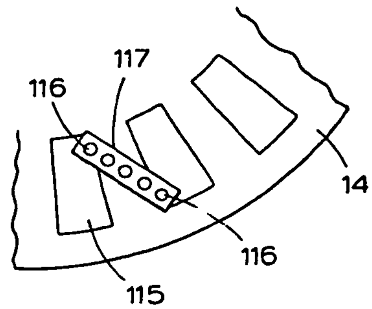

Fig.30

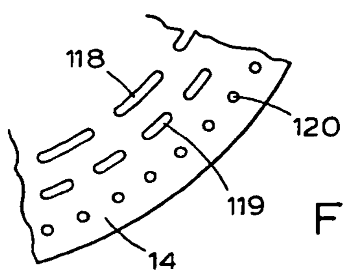

Fig.31

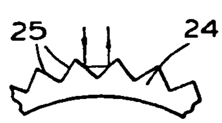

Fig.32

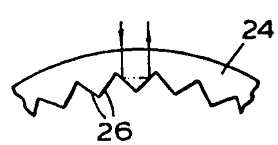

Fig.33

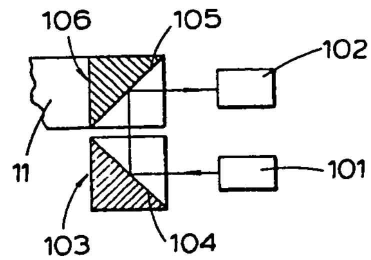

Fig. 34

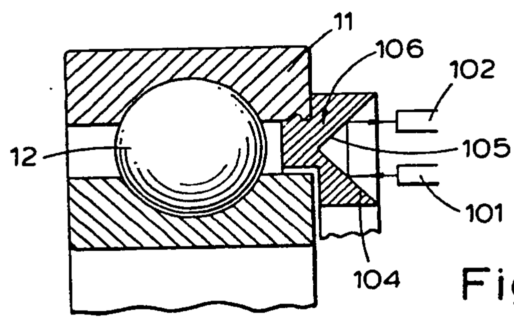

Fig. 35

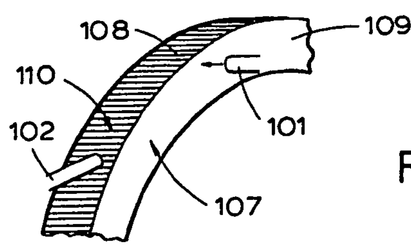

Fig. 36